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Factors Affecting the Usefulness of Honeybees in Pollination[1]

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INTRODUCTION

It has long been recognized that honeybees or other pollinating insects are necessary to the successful production of certain fruit and seed crops. Little has been done, however, to determine the factors that affect their visitation to flowers, or to what extent plants compete with one another for their visits. If orchardists and seed growers know why bees will work on one species of plant while disregarding another that is blooming alongside of it, they should be able to select crops or to manage a rotation which, together with a proper distribution of honeybees, will result in the most effective pollination. For example, in the Pacific Northwest bees prefer the mustard cover crop to the blossoms on the pear trees nearby, and to eliminate the competition the mustard must be removed or replaced by a cover crop that blooms after the fruit has been pollinated.

The honeybees' responses to the attractiveness of various plant species in visiting blossoms for nectar and pollen have been under observation for a number of years in various parts of California and in Oregon. This circular gives some of the data gathered, particularly from experimental colonies in orchards near Camino, Calif., during the fruit-blossoming seasons of 1931, 1932, and 1933.[2]

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[1] A contribution from the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, in cooperation with the University of California.

Camino, a small town in Eldorado County, was found to be ideally situated for intensive observations of the pollen- and nectar-gathering activities of bees and other insects, it being in a typical Sierra Nevada foothill orchard section with the ridges and canyons extending to the west. The orchards were located on top of a ridge, which was flanked on both sides by uncultivated lands, including both timber and manzanita-ceanothus brush.

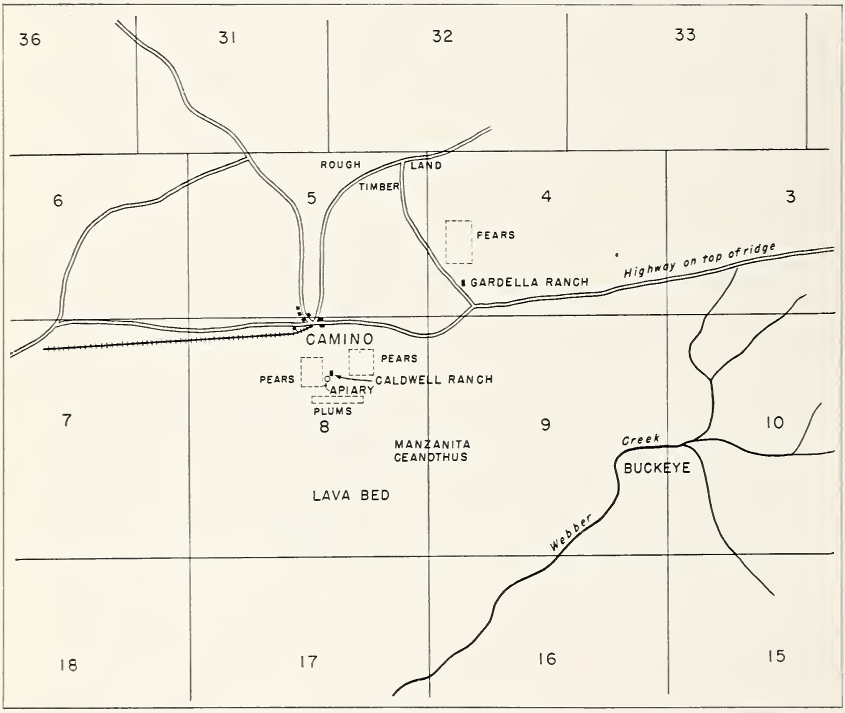

FIGURE 1.—Sketch of area surrounding the apiary at Caldwell's ranch, near Camino, Calif., showing the location of the Caldwell and Gardella orchards.

The distribution of buckeye, a tree poisonous to bees, extended to within bee flight to the south and west. Consequently local colonies of honeybees were scarce, and it was possible to keep track of colonies placed in the orchards for experimental purposes. The uncultivated timber and brush lands should provide an abundant supply of native pollinating insects. If such insects are anywhere sufficient for pollination, it would seem logical to suppose that they might be here. But the growers at Camino had reported difficulty in getting fruit on the trees, especially the pears. Some declared that it was no use to keep bees, for bees would not visit the pears.

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[2] W. A. Caldwell and R. C. Gardella, of Camino, Calif., permitted the use of their properties during this study. I. W. Lilley, farm adviser of Eldorado County, John A. Winkleman, county agricultural commissioner, as well as R. F. Roddan and H. B. Murphy, of the Placerville Fruit Growers' Association, also took a helpful interest in the studies.

The apiary used in the investigations was placed on the Caldwell ranch at Camino, in an open space on top of the ridge along which the orchards extended. Pear orchards were to the east and the west (each 18 acres), and plum orchards (4 acres) were to the south. Observations were also made in a pear orchard on the Gardella

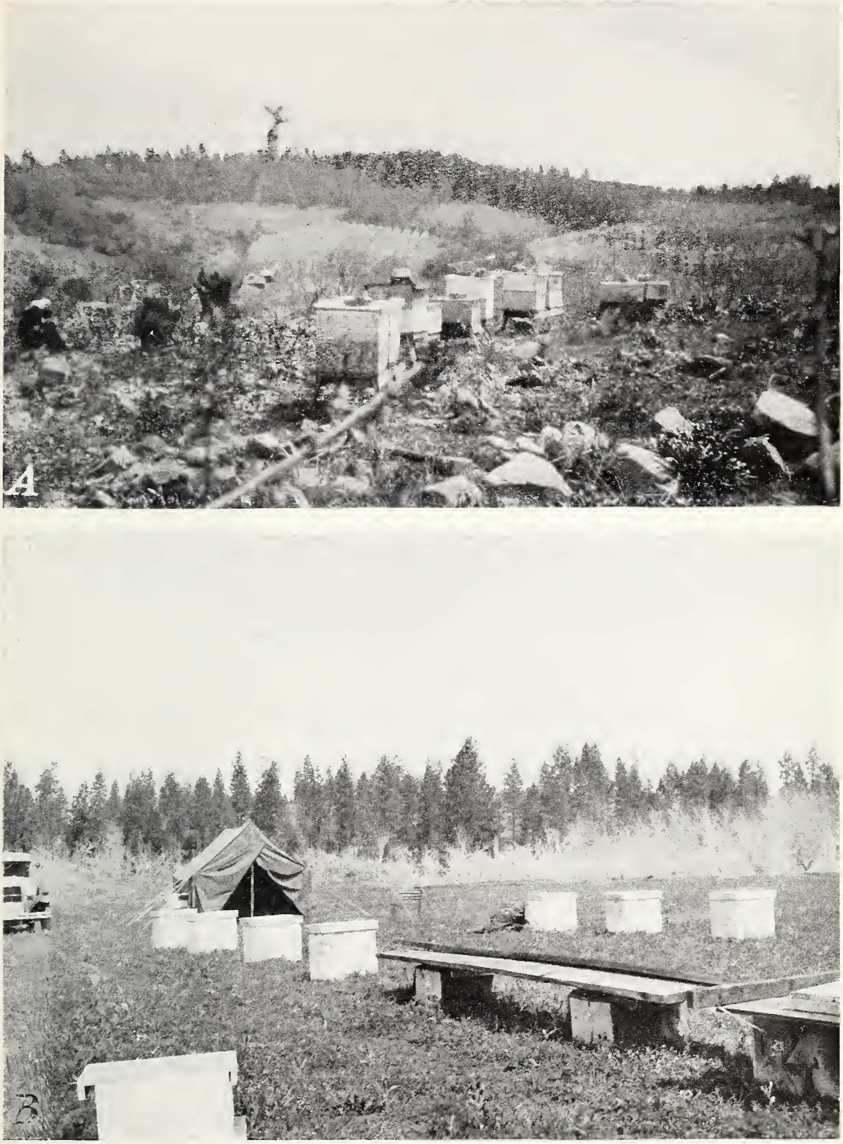

FIGURE 2.—Colonies of bees used for observation purposes in 1932, showing the character of the foothills and the wild land surrounding the orchards. *A*, Gold Hill orchard (west of Placerville, Calif.), elevation 1,800 feet; *B*, Caldwell orchard (Camino, Calif.), elevation 3,300 feet.

ranch, about three-fourths of a mile from the apiary. The map in figure 1 shows the location of the orchards and the apiary. The hives used for observation purposes at Camino in 1932 are shown in figure 2. These photographs show especially the character of the foothill terrain, with orchards interspersed between timber lands. Another small apiary utilized in the foothills west of Placerville (Gold Hill orchard), about 5 miles away, is also shown in figure 2.

METHODS OF STUDY

Bee Counts

Observations in the field supplied the data on the kind and number of insect visitors to the blossoms. Identification of the wild insects was usually only to such well-known groups as blowflies, syrphid flies, small wild bees, bumblebees, and so forth. In making counts the observer circled each tree separately and used field glasses to identify the insects in the tops of the large trees.

Counts were also made of the bees issuing from or entering a hive or package. To avoid disturbing the bees the observer approached the hives from the rear without touching them, lay prone throughout the time necessary, watched the bees with his eye slightly above and to the side of the hive entrance, and when his count was made departed in the direction from which he came.

Attempts were made at first to obtain the flight data with trapping boxes such as were reported by Farrar (*5*)[3] and Woodrow (*12*) as being used with satisfaction, but the congestion outside the entrance during the trapping, as well as the abnormal activity inside, disturbed the bees, and traps were abandoned.

Obtaining the Nectar

The nectar was obtained either from the blossoms or from nectar-collecting bees. Although the sugar concentration of nectar collected by pipette from the blossoms is not always the same as that taken from the honey stomach of bees (caught just as they collected the nectar), by choosing the time and by avoiding for the most part pollen-collecting bees it was possible to use the bee nectar with reasonable accuracy. At low temperatures bees leaving the hive, especially those going for pollen, carry more or less honey, but when weather conditions are suitable for field activity this lunch-carrying habit is apparently abandoned. The opinion was long prevalent that bees extract and discard water from nectar while carrying it to the hive, but Park (*8*) has disproved this theory.

Glass tubing drawn to appropriate sizes and shapes was used to collect the nectar from the blossoms. For concentrated nectars a rubber pipette bulb was advantageous. When the quantity of nectar was meager, it was difficult to secure a sample of hand-collected nectar even with the expenditure of much time.

To obtain nectar from the bee, the bee was anesthetized in a cyanide bottle, and the honey stomach was removed by carefully opening the abdominal wall with the fingers. The contents of the sac were then quickly placed in the refractometer. When full the nectar stomach contained about 30 to 35 microliters.

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[3] Italic numbers in parentheses refer to Literature Cited, p. 31.

Sugar Concentration of Nectars

The sugar concentration of the nectars was determined by means of a refractometer with a sugar scale, which indicates the percentage of total sugars. The kinds of sugar present, whether sucrose or simpler sugars, vary with the plant, and were not considered in this study. The instrument was constructed to read accurately at 68° F., but except for preliminary trials a constant temperature was not maintained in the field and corrections were not made. The sugar-scale readings are therefore only relative.

Identification of Pollen

Pollen grains can be identified as to source by examination of their structure, color, and size. The identification of pollens has been studied by Wodehouse (*11*), Parker (*9*), Zander (*13*), Armbruster (*1*), and Jacobs (*6*).

When pollen is plentiful afield, the honeybee seldom mixes two kinds in one load. Many pollens, in bee-load quantity, have a characteristic color and texture, and no difficulty was encountered in distinguishing loads of pear, plum, and mustard pollen by the color and the consistency.

In addition to gross separation by observation, pollen samples were transferred from the bees' legs to gelatin capsules for microscopical examination. Pollens from the blossom anthers were likewise collected and compared with pollens taken from the bees.

INSECTS GATHERING POLLEN OR NECTAR ON FRUIT BLOSSOMS

Some of the data obtained on the visitation of honeybees and other insects to normal blossoms, especially within the pear orchards, appear in tables 1 to 7.

In the Camino district honeybees were the most common visitors to the blossoms, blowflies were next, and other insects were scarce. As a rule honeybees visit the blossoms of only one plant species on each field trip, while most other insects frequently shift from one species to another. For this reason no other insect compares favorably with the honeybee in pollen-distributing activity. Only honeybees and wild bees collected pollen for removal to their nests. Ants were surprisingly common in the orchard blossoms, feeding on nectar at temperatures well below that at which flying insects cease activity. Ants were observed working in early morning, late evening, and during cold rainy periods, but probably they do not often move from tree to tree. Pollen seemed to offer no special attraction to them, but nectar and possibly sap did, because frequently these ants were engaged in taking nectar and in biting into tender twigs and the tiny fruit before the petals had fallen away.

Bumblebees worked in the orchards during periods far too cold for the honeybee. Andrenids and other small bees were very sensitive to wind movement; they hung to leeward, and as a breeze increased to a gentle wind they disappeared. Honeybees were only slightly affected by a breeze of sufficient velocity to stop the andrenids. Wild bees were more in evidence near uncultivated lands. Blowflies were extremely active on pear blossoms, particularly for several hours before a rain. They also appeared on the sunny sides of tree trunks and limbs, and fed freely upon the fluid oozing from blight infections, where no honeybees were found. Syrphid flies evidently fed more or less on the pollen, but the chief interest of flies in general was in nectar.

The insect visitors to certain fruit blossoms in a single day in 1932 are shown in table 1. There was a wide difference in the number of honeybees visiting different species of fruit blossoms, and even different varieties within a species. For example, the ratio between the Delicious and an unknown variety of apple was greater than 3. The same ratio existed between Winter Nelis and Bartlett pear, and a ratio of 2 between Royal Ann cherry and Gros plum blossoms. As compared with honeybees, other insect visitors, except blowflies, were limited in number.

TABLE 1.—*Insect visitors to 4 species of fruit-tree blossoms on April 8, 1932, at Camino, Calif.*

Kind of blossom	Time of day	Honeybees	Blowflies	Syrphid flies	Small wild bees	Bombyliid flies	Others (mostly bumblebees)
		Number	*Number*	*Number*	*Number*	*Number*	*Number*
Apple:							
Unknown variety	8:40 a. m. to 5:55 p. m.	539	6	0	45	7	1
Delicious	do	1,630	17	0	48	3	9
Pear:							
Bartlett	8:30 a. m. to 2 p. m.	47	45	0	9	2	0
Winter Nelis	do	142	49	2	11	4	0
Cherry, Royal Ann	8:50 a. m. to 9 a. m.	28	0	0	0	0	0
Plum, Gros	do	60	0	0	1	0	1

The total numbers of insect visitors observed in the orchards at Camino in 1932 and 1933 are presented in table 2. Note the abundance of the honeybee as compared with the other insects.

TABLE 2.—*Comparison of insect visitors observed on apple, cherry, pear, and plum blossoms at Camino, Calif., during the seasons of 1932 and 1933*

Insects	Number of insects	Percent of total visitors	Insects	Number of insects	Percent of total visitors
Honeybees	10,774	82.3	Leaf-cutter bees	33	0.2
Blowflies	926	7.1	Others	230	1.8
Small wild bees	759	5.8			
Syrphid flies	200	1.5	Total	13,086	100.0
Bombyliid flies	164	1.3			

The insect visitors to a Bartlett pear tree for 1 day in 1932 are shown in table 3. This tree was 400 feet from the apiary. Note the rise and fall in bee population (see also fig. 3) during the day. Bees were numerous enough at this distance from the apiary to be extremely valuable pollen distributors. The honeybees collected only pollen from the pear tree, although they visited manzanita, plum, and early apple blossoms for nectar during the same period.

TABLE 3.—*Insect visitors to Bartlett pear blossoms for 15-minute periods throughout 1 day (Apr. 5, 1932) at Camino, Calif.*

Time of observation	Honeybees	Blowflies	Syrphid flies	Bumblebees
	Number	*Number*	*Number*	*Number*
8:30 to 8:45 a. m	0	0	0	0
9 to 9:15 a. m	6	2	1	0
9:30 to 9:45 a. m	9	2	0	0
10 to 10:15 a. m	7	2	0	1
10:30 to 10:45 a. m	10	5	0	1
11 to 11:15 a. m	8	1	0	0
11:30 a. m. to 12 m	7	0	0	0
1 to 1:15 p. m	9	0	1	0
1:30 to 1:45 p. m	4	0	0	0
2 to 2:15 p. m	3	0	0	0
2:30 to 2:45 p. m	6	1	0	1
3 to 3:15 p. m	2	0	0	0
3:45 to 4 p. m	2	0	0	0
5:05 to 5:20 p. m	0	0	0	0
Total	73	13	2	3
Percent of total	80. 2	14. 3	2. 2	3. 3

Data on the honeybee and blowfly visitors to blossoms on a Bartlett and a Winter Nelis pear tree at Camino for 1 day in 1933 are given in table 4. The 2 trees were about 800 feet from the apiary. They were observed alternately for 5-minute periods from 8:10 a. m. to 4:45 p. m., but the records have been condensed into four periods because this arrangement indicates the characteristic rise and fall in bee population. (See also fig. 3.) Bees were plentiful on both varieties, but more than twice as many visited the Winter Nelis. Honeybees were consistently the outstanding visitors, being about 75 percent of the total. They visited the Bartlett tree for pollen only, the Winter Nelis for both nectar and pollen. In addition, 17 syrphid flies, 15 small wild bees, 7 bombyliid flies, 7 bumblebees, and 2 other insects were observed on the 2 trees, representing 14 percent of the total number of insect visitors.

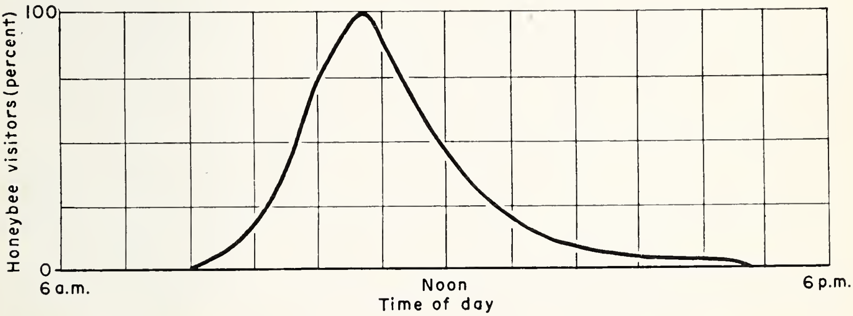

FIGURE 3.—Honeybees found on Bartlett pear blossoms at different times of day, in percentage of the peak before noon.

A graph based on the observations made at Camino during the three seasons (fig. 3) vividly illustrates the nature of the daily honeybee population on a Bartlett pear tree. Visitation usually began by 8 or 8:30 a. m., increased to a distinct peak before midday, and then decreased to nothing. The drop in population following the peak of the morning pollen-gathering activity was frequently sharp when the attractive apple and manzanita nectars were available.

TABLE 4.—*Number of honeybees and blowflies visiting Bartlett and Winter Nelis pear blossoms between 8:10 a. m. and 4:45 p. m., April 21, 1933, at Camino, Calif.*

Variety of blossom	Insects	Visitors between—					Percent of total insect visitors
		8:10 and 10 a. m.	10:15 a. m. and 12:15 p. m.	12:20 and 2:20 p. m.	2:30 and 4:45 p. m.	Total	
		Number	*Number*	*Number*	*Number*	*Number*	
Bartlett	Honeybees	20	30	24	7	81	23
	Blowflies	2	5	5	0	12	3
Winter Nelis	Honeybees	38	62	43	37	180	51
	Blowflies	6	7	13	7	33	9

The effect of distance on honeybee visitation to Bartlett pear blossoms is illustrated by the data in table 5. At the three specified periods counts were made of honeybees visiting the trees in two rows of the Caldwell orchard. The trees in this block are spaced 20 feet apart, so that tree No. 30 was 580 feet from tree No. 1, which was closest to the apiary. It can be seen from the table that at any given time of day the number of bees on the trees nearest the apiary greatly exceeded the number on the trees farthest away. Numerous samples of such data were taken over the 3-year observation period, but all are essentially similar.

TABLE 5.—*Bee visitors to pear blossoms in relation to distance away from the apiary, during 3 sample periods in the Caldwell orchard, Camino, Calif.*

Tree Nos.[1]	Honeybees observed on—			Tree Nos.[1]	Honeybees observed on—		
	Row 12, Apr. 5, 1932, 2:04 to 2:40 p. m.	Row 3			Row 12, Apr. 5, 1932, 2:04 to 2:40 p. m.	Row 3	
		Apr. 14, 1933, 8:10 to 8:45 a. m.	Apr. 15, 1933, 8 to 8:40 a. m.			Apr. 14, 1933, 8:10 to 8:45 a. m.	Apr. 15, 1933, 8 to 8:40 a. m.
	Number	*Number*	*Number*		*Number*	*Number*	*Number*
1 to 5	6	5	7	16 to 20	4	3	3
6 to 10	10	5	5	21 to 25	1	1	2
11 to 15	5	2	4	26 to 30	2	0	0

[1] Trees are numbered progressively down the rows away from the apiary.

The few insect visitors to four rows of pear trees in the Gardella orchard for one period are listed in table 6. This orchard was much farther from the apiary than the Caldwell orchard, and honeybee visitors were consistently few. On the Bartlett pear trees only 3 bees were observed, as compared with 123 bees, or an average of 3.3 bees per tree, in one block of the Caldwell orchard just before 11 o'clock. In the Gardella orchard, however, the honeybees were abundant on the seedling cherry and apple trees nearby. At 12:15 p. m. from 30 to 40 bees were on each cherry tree (30 feet tall) and 15 to 20 bees on each apple tree (18 feet tall).

On Bartlett pear blossoms the pollen-collecting bees were frequently plentiful on trees within 800 feet of the apiary, but the number diminished rapidly with increasing distance from the apiary. Since there was a surplus of pollen within a short distance, the bees apparently satisfied their needs without going far. On the other hand, bees were found flying some distance to obtain nectar. For example, bees were abundant on sweet cherry, apple, and manzanita blossoms more than 2,500 feet from the hive.

TABLE 6.—*Insect visitors to Bartlett and Bosc pear blossoms on April 6, 1932, 11 a. m. to 12:30 p. m., in Gardella orchard, Camino, Calif.*

Variety and location of trees	Honeybees	Blowflies	Syrphid flies	Leaf-cutter bees	Small wild bees	Bombyliid flies
Bartlett:	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Row 1, trees 1 to 18	3	6	0	1	0	1
Row 14, trees 1 to 20	0	0	0	0	0	1
Bosc:						
Row 1, trees 1 to 12	1	1	1	0	1	2
Row 13, trees 1 to 12	0	1	1	0	4	2
Total	4	8	2	1	5	6

A summary of the numerous observed insect visitors to pear blossoms in the Caldwell orchard for 1932 and 1933 is given in table 7. The number of honeybees exceeds the total of all the other visitors. Perhaps even these favorable figures do not give an adequate indication of the importance of honeybees as distributors of pear pollen, because many of the observations were made during the less favorable periods of the day; that is, honeybees were at times scarce on pear blossoms from late in the morning throughout the working hours.

TABLE 7.—*Insect visitors to pear blossoms at the Caldwell orchard, Camino, Calif., 1932 and 1933*

Date	Honeybees	Blowflies	Syrphid flies	Leaf-cutter bees	Small wild bees	Bombyliid flies	Others
1932	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Mar. 30	199	36	2	1	10	5	1
31	140	31	13	0	29	18	3
Apr. 1	3	0	2	0	2	1	0
3	84	9	9	1	0	0	2
5	190	30	11	2	5	3	6
6	418	202	60	3	15	11	6
7	159	120	3	0	41	9	0
8	195	96	3	0	25	6	1
9	153	177	7	0	32	10	0
14	8	3	4	2	19	1	2
1933							
Apr. 10	112	52	19	0	17	16	16
13	44	20	9	0	7	10	9
14	26	13	9	0	8	1	3
15	38	24	14	0	7	2	6
19	84	3	3	0	2	3	1
20	48	3	0	0	1	0	0
21	296	52	0	0	13	7	9
22	74	10	5	0	0	0	0
23	48	0	0	0	0	0	0
24	63	2	0	0	0	0	0
27	63	11	0	0	0	0	0
Total	2,445	894	173	9	233	103	65
Percent of total visitors	62.3	22.8	4.4	0.2	6.0	2.6	1.7

Although blowflies made up 23 percent of the visitors to the pear trees, it is not likely that they are so helpful in distributing pear pollen as the percentage would seem to indicate. The rather consistent association of blowflies with pear trees suggests that they are attracted to these trees by some odor. However, their habit of walking about the trunk, limbs, leaves, and blossoms does not appear conducive to effective pollination. They lap their tongues down here and there as if in search of food. Pollen was not observed being collected or eaten. At night and during cold snaps blowflies were observed to take refuge in the piles of blighted and freshly cut pear twigs about the orchards.

From the foregoing data one can conclude that the honeybees are practically the only distributors of pear pollen. It is obvious that part of the difficulty of the Camino growers in getting fruit on their pear trees has been due to the absence of bees within the orchards.

PLANT CHARACTERISTICS

Nectar is a secretion from specialized glands in a plant and is composed primarily of sugars dissolved in water. The various types of plants have nectar glands of different structure and position. For example, many fruit blossoms are cup-shaped, those of manzanita are juglike, while in vetch extrafloral nectaries occur on the leaves. In many plant species nectar does not appear until after the blossoms are open; at least two, however, the orange and the manzanita, secrete nectar before the blossoms open.

Structure and Position of Nectar Glands

A knowledge of the structure of the blossoms is necessary to an understanding of the changes that may occur in the nectar, for if the nectar is exposed to dry air the water evaporates, leaving a higher percentage of sugars. If there is a wind, the rate of evaporation is increased. Furthermore, as the relative humidity of the atmosphere decreases, the sugar concentration of the nectar increases. On a clear day the relative humidity frequently drops from near 100 percent in early morning to less than 50 percent at noon. It was found, in an experiment under controlled conditions, that when the relative humidity was 100 percent the sugar concentration of poinsettia nectar was 12.8 percent, but when the humidity had been 70 percent for several hours the concentration had increased to 61.6 percent.

The general structures of four kinds of fruit blossoms, as pertaining to nectar secretion and pollen, are pictured in figure 4. Unlike the plum and nectarine, the pear does not have a deep cup lined with nectar tissue, but only small, slitlike openings in the flat top surface between the petals and the stamens, as shown in figure 5. The cup of the almond is deep, but the nonsecreting hairy area is extensive. In contrast manzanita blossoms have a deep, constricted cup, as shown in figure 6.

Visits to Emasculated Blossoms

It is common practice in plant breeding to tie bags, in order to exclude insects, over blossoms that have been hand-pollinated. Pinching away the petals and stamens of pollinated blossoms has been used in lieu of bagging on the assumption that insects do not visit blossoms thus treated, but observations in orchards at Davis revealed

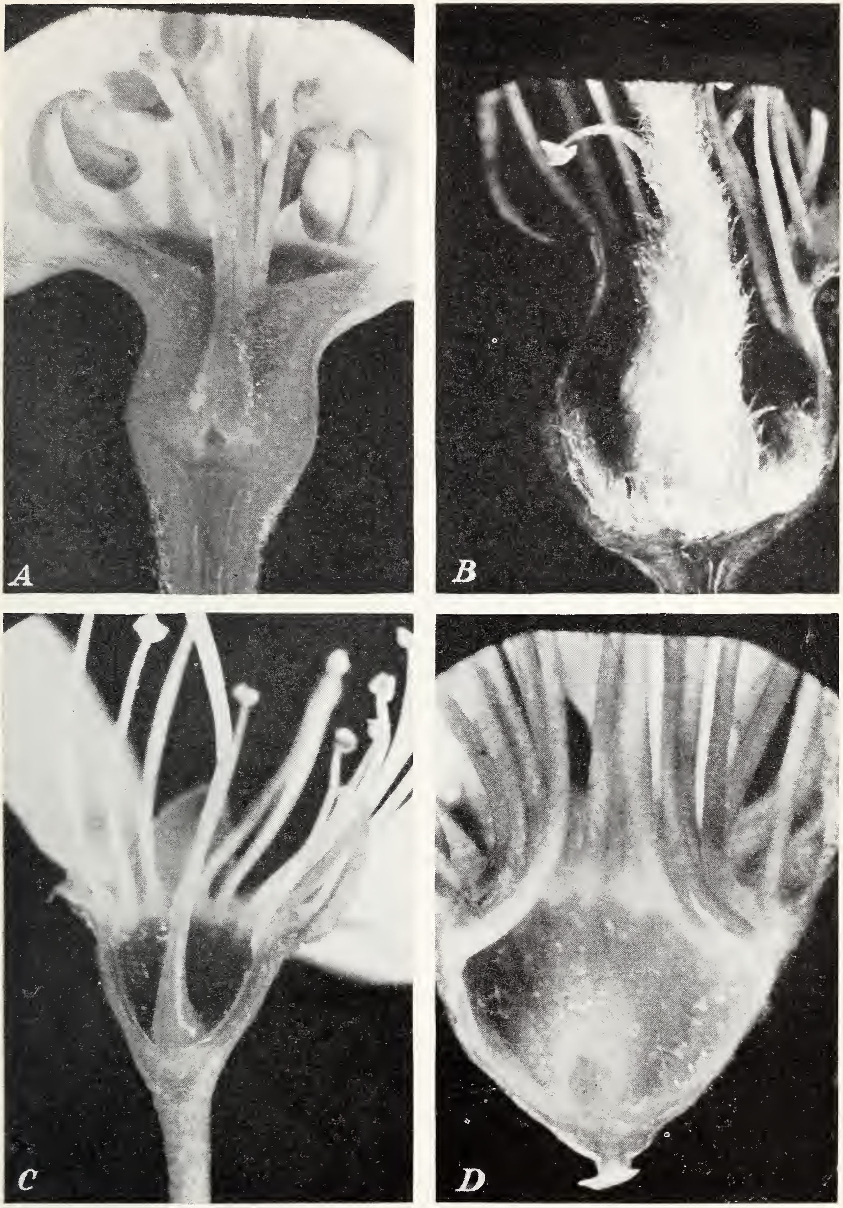

Figure 4.—Longitudinal sections of fruit blossoms: *A*, Bartlett pear with extremely large anthers and very small nectar-secreting areas in the narrow slits; *B*, almond, with limited secreting surface; i. e., the nonhairy areas secrete nectar rather copiously; *C*, plum; and *D*, nectarine, with large areas for secretion, i. e., the entire inside surface of the cup.

honeybee visitors on such emasculated blossoms. In a number of cases, especially on apricot and nectarine, which are heavy producers of nectar, honeybees worked such blossoms in large numbers. These blossoms are as productive of nectar as those bearing the showy petals and stamens, for the nectar glands are on the wall of the deep cup (fig. 4, *D*) which remains on the plant after emasculation. It therefore appears to be unsafe to depend on emasculation for plant-breeding purposes.

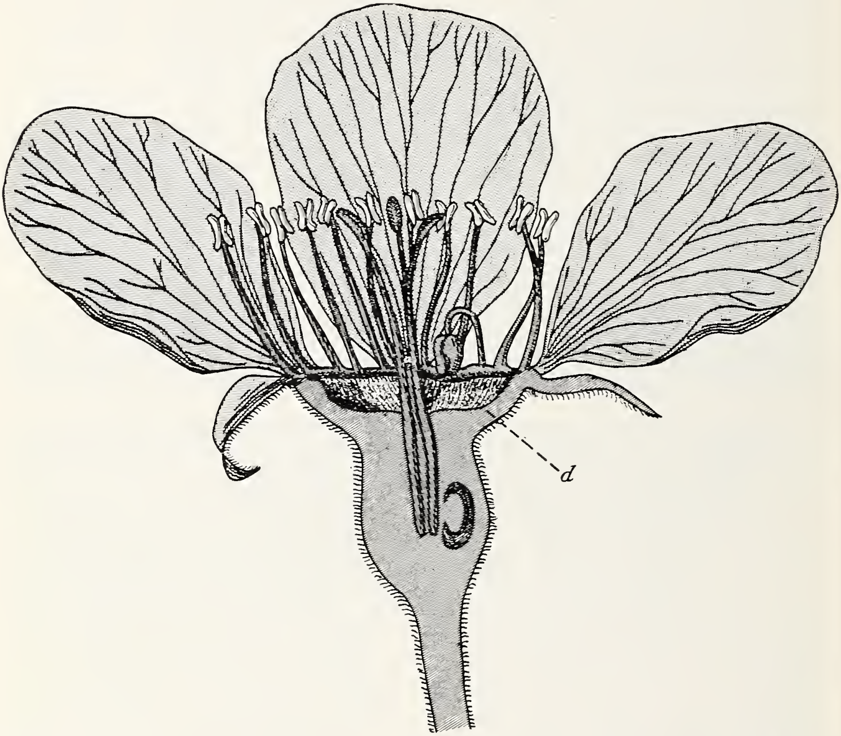

FIGURE 5.—Sketch of pear blossom in longitudinal section (by M. B. Waite). Nectar issues from five slits in the disk area, *d*.

SUGAR CONCENTRATION OF VARIOUS NECTARS

Numerous observations revealed a wide variation both in the quantity and in the sugar concentration of nectar from different plants. For instance, the quantity taken from a single blossom of alfalfa was only 0.83 microliter, while that from a single orange blossom amounted to more than 40 microliters. There was a difference not only between species of plants but also between the varieties of the same species. At Hood River, Oreg., on April 29, 1935, the Winter Nelis and Easter pears possessed abundant nectar, the Bartlett pear had a medium quantity, and the Anjou pear had practically none. At Davis, Calif., on March 31, 1933, the average sugar concentrations of various nectars were as follows: Apple, 46.2; peach and nectarine, 28.9; plum, 25.8; sour cherry, 23.5; Winter Nelis pear, 9.9; and Bartlett pear, 7.9 percent.

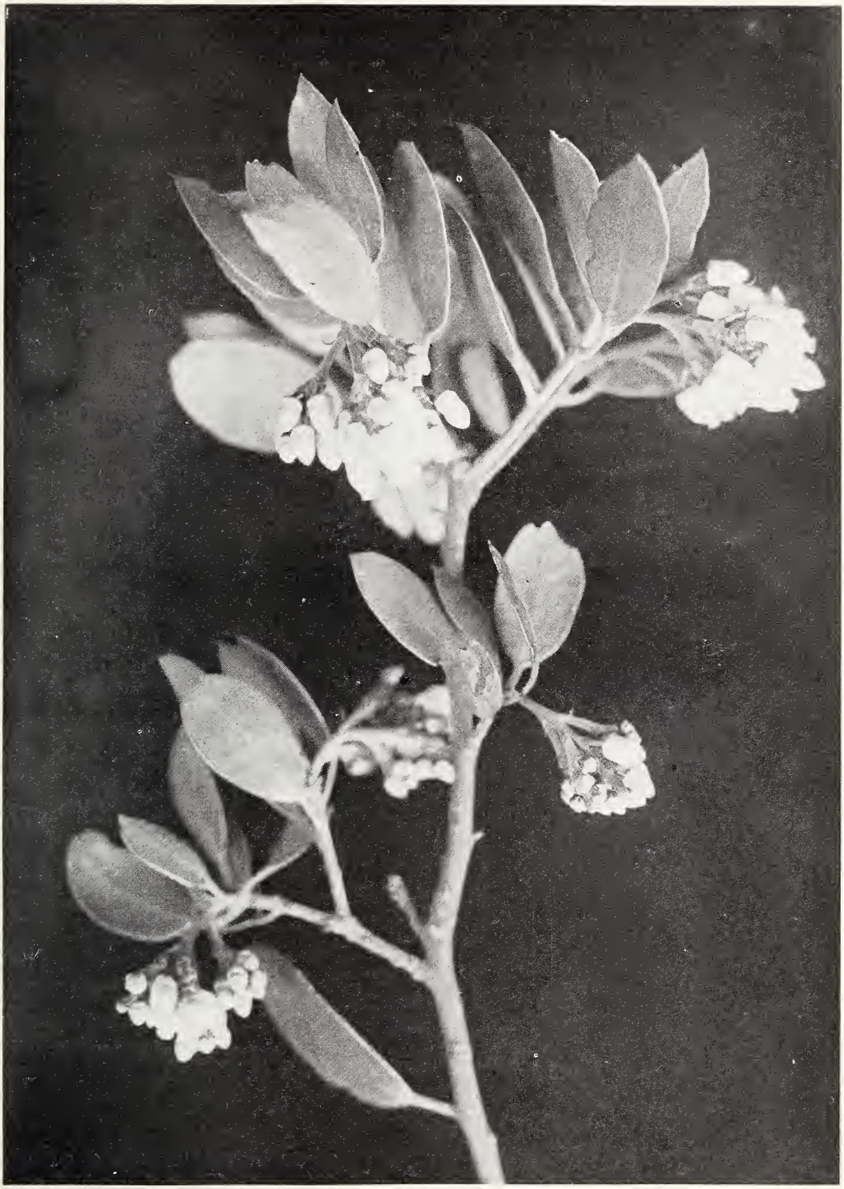

FIGURE 6.—Manzanita, showing juglike blossoms. Nectar in such blossoms is much less sensitive to changes in humidity than that in open-type blossoms. (Photograph by J. M. Goodyear.)

Detailed data are presented for nectars from pear, plum, apple, cherry, manzanita, and miscellaneous blossoms.

PEAR

The Bartlett pear was found to provide only a small quantity of nectar at Camino, and the sugar concentration in the limited number of procurable samples was low. For some unknown reason the Bartlett pear blossoms in the Sacramento Valley afforded more nectar than those at Camino, but they have never been observed to secrete so freely as do other fruits or even certain other varieties of pear, such as Winter Nelis. On March 31, 1933, at Davis, three men obtained, between 9 a. m. and 12 m., enough Bartlett pear nectar for a few sugar determinations. Hundreds of blossoms were worked over with pipettes in securing the nectar from Bartlett, whereas nectar was readily obtainable from Winter Nelis. The sugar concentration for Bartlett may be below the point of attractiveness to the honeybees, at least when other richer nectars are available. Honeybees were busily gathering nectar from the plum blossoms close to the pear trees, but they visited the pear only for pollen.

The details for the two varieties of pears are shown in table 8. It will be noted that the sugar concentration of the nectar increased during the morning as the temperature increased and the relative humidity decreased.

TABLE 8.—*Sugar concentration of nectar from Bartlett and Winter Nelis pear blossoms at different times in the morning, March 31, 1933,*[1] *Davis, Calif.*

Variety	Time of morning	Sugar concentration of nectar
		Percent
Bartlett	9	2.8
	9:05	2.8
	9:10	4.2
	9:18	5.5
	9:27	3.8
	10	4.4
	10:10	5.2
	11:17	7.2
	11:24	9.0
	11:38	20.5
	11:50	13.0
	12	17.0
	Average	7.9
Winter Nelis	8 to 8:30	2.1
	9:18	5.5
	11	15.0
	11:10	17.0
	Average	9.9

[1] A clear morning with a slight movement of air from the north. The temperature changed from 56° to 68° F., and the relative humidity from 99 to 65 percent during the observations.

PLUM

Many plum varieties secrete nectar in abundance, while others secrete little. The nectars from French (Agen), Gros (Pond),[4] and President blossoms at Camino were richer in sugar than was that from Bartlett pear. These plum blossoms were attractive to bees when other nectars of higher sugar concentration were not available. Kelsey plums secreted practically no nectar at Davis in 1937, and bees did not even visit them for pollen.

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[4] The names "French" and "Gros," instead of "Agen" and "Pond," appear in this circular because of common usage on the Pacific coast.

Some plum blossoms are of open cup shape, and in such blossoms the sugar concentration of the nectar is readily affected by the relative amount of moisture in the surrounding air. Some data for Gros plums, showing the increase in the sugar concentration as the air became somewhat drier during the day, are given in table 9.

Table 9.—*Sugar concentration of hand-collected nectar from Gros plum blossoms at different times of day on April 22* [1], *1933, Camino, Calif.*

Time of day	Samples	Blossoms used in sample	Sugar concentration of nectar	
			Range	Average
	Number	*Number*	*Percent*	*Percent*
8:15 to 8:43 a. m.	5	4–15	17.1–24.0	20.1
9:22 to 9:39 a. m.	6	1–6	23.4–31.8	28.1
10:22 to 10:45 a. m.	9	1–4	23.1–33.5	28.5
3:55 to 4:35 p. m.	19	2–10	25.6–45.5	37.6

[1] A fair, warm day except for a brief cloudy period in midafternoon. The temperature changed from 63° to 70° F. and the relative humidity from 55 to 45 percent during the observations.

Nectar samples collected concurrently from plum blossoms and from the bees working on them agree closely in sugar concentration, as shown in table 10 for President, Gros, and French nectars. No significant difference in sugar concentration was noted for the nectars of these three varieties. On some days, however, the concentrations are well above those obtained on other days.

Table 10.—*Sugar concentration of plum nectar taken from blossoms and from bees in April 1933, Camino, Calif.*

Variety	Date in April	Nectar from bees		Nectar from blossoms	
		Samples	Average sugar concentration	Samples	Average sugar concentration
		Number	*Percent*	*Number*	*Percent*
President	13	24	40.5	3	37.6
Gros	13	5	41.0	14	36.2
	14	10	39.4	7	38.2
	15	5	52.1	11	48.4
	24	10	42.3	6	42.1
French	14	4	40.6	5	37.1

The sugar concentration of plum nectar at any given time may also differ with the variety. On the morning of March 17, 1935, the average concentrations for eight varieties (Maynard, Gee Whiz, Eldorado, Miss Edith, Shiro, Etta, First, and Milton) ranged from 10 to 28 percent at Davis, and three other varieties (Kelsey, Better Than Gold, and Kingdom Come) in the same orchard had no nectar. All the trees were in full blossom and had received the same treatment as to irrigation, pruning, etc.

APPLE AND CHERRY

Apple and sweet cherry blossoms are extremely attractive to the honeybee for nectar. Bees at times practically abandon all other fruit blossoms for these two kinds. The reason for preference is apparent when the sugar concentrations of these nectars and the other fruit nectars are compared (table 13). Sour cherry nectar showed a much lower sugar value than nectar from the sweet cherry. Secretion was copious, however, and bees collected this nectar freely, especially late in the day, after richer nectars had been harvested and the evaporation of water had increased its concentration.

The richness of the nectars from Delicious and Steel's Red apple blossoms is shown by tests of the sugar concentration at Camino from 2:40 to 4:30 p. m. on April 27, 1933. The average percentage of the Delicious was 53.9, with a range from 45.2 to 57.3; and the average percentage of Steel's Red was 50.1, with a range from 46.3 to 52.4. These apple trees were approximately 1.25 miles from the apiary, but because of the attractiveness of apple nectar the bees were flying out of the pear orchard, across the manzanita, and into the apples. The day was warm, calm, and dry. Both varieties were visited by large numbers of honeybees, but visitors on Delicious were plainly more numerous.

MANZANITA

Manzanita freely secretes colorless nectar. Thousands of nectar bees were observed visiting manzanita blossoms, but no interest was displayed in pollen. These plants attract nectar-collecting bees away from certain fruit blossoms which are deficient in either the quantity or the quality of nectar. Often a general shift of bees from Bartlett pear, a pollen source, to the manzanita blossoms with their rich nectar was discernible in midforenoon.

In general the plants most advanced in blossoming afforded the richest nectar. The blossoms just about to open had nectar of concentration well below that from blossoms open to the air. In 1932 two observers, working independently and concurrently, found bees definitely selecting manzanita bushes so far advanced that the blossoms were lying upon the ground, in preference to plants with recently opened blossoms. Again in 1933 bees on manzanita were selecting blossoms with the richer nectar, abandoning some of the blossoms with a quantity of thin nectar after examining them. The percentages of sugars found in the unopened and open manzanita blossoms in 1933 appear in table 11. Table 12 shows concentrations of manzanita nectar obtained from the bees in both years.

TABLE 11.—*Sugar concentration of nectar from unopened and open manzanita blossoms, April 1933, Camino, Calif.*

Date	Relative humidity	Unopened blossoms			Open blossoms		
		Samples	Range	Average	Samples	Range	Average
	Percent	*Number*	*Percent*	*Percent*	*Number*	*Percent*	*Percent*
Apr. 19	68	3	16.2–18.2	16.6	7	24.3–34.5	26.1
20	62	3	16.6–19.0	18.1	2	32.0–34.0	33.0
22	46				6	33.2–43.9	37.6
28	60	2	15.8–18.2	17.0	9	32.2–34.9	33.7

TABLE 12.—*Sugar concentration of bee-collected manzanita nectar collected between 11 and 11:40 a. m. on 2 dates, Camino, Calif.*

Date	Temperature	Relative humidity	Elevation	Samples	Sugar concentration	
					Range	Average
	°*F.*	*Percent*	*Feet*	*Number*	*Percent*	*Percent*
Apr. 6, 1932	59		3,325	10	41.8–51.0	47.8
Apr. 28, 1933	63	68	3,100	11	38.1–47.3	43.1

These observations confirm the statements of beekeepers that the yield of manzanita honey improves near the end of the blossoming period. It was previously supposed that the weather was responsible, since manzanita is an early plant and the weather later in the season was more favorable for field work by the bees.

MISCELLANEOUS PLANTS

Data on the average sugar concentrations of several other plants, collected during a number of seasons and from many locations, have been accumulated and are presented in table 13, the plants being listed according to the descending order of the sugar concentration of their nectar.

TABLE 13.—*Sugar concentrations of the nectars of some California and Oregon plants, arranged in order of decreasing sugar*

Plant	Average sugar concentration	Plant	Average sugar concentration
	Percent		*Percent*
Alfileria (*Erodium cicutarium* (L.) L'Her.)	65.0	Cantaloup (*Cucumis melo* L.)	46.7
Black locust (*Robinia pseudoacacia* L.)	63.2	Perennial sunflower (*Wyethia angustifolia* (D. C.) Nutt., Oregon)	45.8
Willows (*Salix* spp.)	60.0	Jackass clover (*Wislizenia refracta* Engelm.)	45.3
Locoweed (*Astragalus pachypus* Greene)	59.2	Oregon grape (*Berberis aquifolium* Pursh)	45.0
Wild buckwheat (*Eriogonum fasciculatum* Benth.)	58.1	Apple (*Malus pumila* Mill.)	45–55
Common vetch (*Vicia sativa* L., extrafloral nectar)	56.5	Black sage (*Salvia mellifera* Greene)	44.9
Sainfoin (*Onobrychis viciaefolia* Scop.)	55.4	Toyon (*Photinia arbutifolia* Lindl.)	44.8
Bachelor's-button (*Centaurea cyanus* L.)	52.5	Jim Hill mustard (*Sisymbrium altissimum* L.)	44.1
Melanops vetch (*Vicia melanops* Sibth. and Sm., extrafloral nectar)	52.1	Hairy vetch (*Vicia villosa* Roth)	44.0
Bigleaf maple (*Acer macrophyllum* Pursh)	52.0	Alsike clover (*Trifolium hybridum* L.)	43.3
Deerweed (*Lotus scoparius* (Nutt.) Ottley)	52.0	Locoweed (*Astragalus hornii* Gray)	42.4
Yellow sweetclover (*Melilotus officinalis* (L.) Lam.)	51.6	Vine maple (*Acer circinatum* Pursh)	42.0
Dandelion (*Taraxacum palustre* var. *vulgare* (Lam.) Fernald)	51.2	Cotton (*Gossypium hirsutum* L., Acala variety, extrafloral nectar)	41.9
Rape (*Brassica napus* L.)	50.5	Buckeye (*Aesculus californica* Nutt., wide range, 33.0–50.8 [2])	41.5
Wild buckwheat (*Eriogonum* sp., annual pink, from eastern Oregon)	50.5	Alfalfa (*Medicago sativa* L., except Imperial Valley data)	41.1
Salal (*Gaultheria shallon* Pursh)	50.5	White clover, ordinary and ladino (*Trifolium repens* L.)	41.0
Chickweed (*Stellaria media* (L.) Cyr.)	50.0	Spikeweed (*Hemizonia pungens* (Hook. and Arn.) T. and G.)	39.9
Common mustard (*Brassica campestris* L.)	50.0	Privet (*Ligustrum* sp.)	39.2
Sweet cherry (*Prunus avium* L.)	[1] 50–60	Tamarisk (*Tamarix* sp.)	38.8
Flax (*Linum usitatissimum* L.)	49.5	Wireweed wild buckwheat (*Eriogonum* sp., California)	37.8
Cultivated buckwheat (*Fagopyrum esculentum* Moench)	49.0	Yellow star-thistle (*Centaurea solstitialis* L.)	37.5
Horsechestnut (*Aesculus hippocastanum* L.)	49.0	Penstemon (*Penstemon* sp.)	37.3
Hoarhound (*Marrubium vulgare* L.)	48.3	Wild buckwheat (*Eriogonum* sp., yellow perennial)	37.3
White sage (*Salvia apiana* Jeps.)	48.0	Milkweed (*Asclepias speciosa* Torr.)	37.2
Castor-bean (*Ricinus communis* L., extrafloral nectar)	47.8	Incense-cedar (*Libocedrus decurrens* Torr., honeydew)	36.3
Hungarian vetch (*Vicia pannonica* Crantz, extrafloral nectar)	47.7		
Crimson clover (*Trifolium incarnatum* L.)	47.7		

[1] Two figures indicates a range between varieties or species.

[2] Ruth Beutler (*2*), in Germany, reported red buckeye with a sugar concentration of 66 percent.

TABLE 13.—*Sugar concentrations of the nectars of some California and Oregon plants, arranged in order of decreasing sugar*—Continued

Plant	Average sugar concentration
	Percent
Aster (*Aster spinosus* Benth.)	36.2
White sweetclover (*Melilotus alba* Desr., except Imperial Valley data)	35.8
Evergreen blackberry (*Rubus laciniatus* Willd.)	35.6
Fireweed (*Epilobium angustifolium* L.), wide variations with varying humidity	35.0
Canada thistle (*Cirsium arvense* (L.) Scop.)	35.0
Red clover (*Trifolium pratense* L.)	34.3
Linden (*Tilia* spp.)	33.6
Locoweed (*Astragalus watsoni* Sheld.)	33.3
Strawberry clover (*Trifolium fragiferum* L.)	33.3
Fenugreek (*Trigonella foenum-graecum* L.)	32.9
Creeping sage (*Salvia sonomensis* Greene)	32.4
Monkeyflower (*Mimulus* sp.)	32.0
Sunflower (*Helianthus annuus* L.)	31.6
Red gum (*Eucalyptus camaldulensis* Dehn.)	30.0
Peach and nectarine (*Prunus persica* (L.) Batsch. and *P. persica* var. *nectarina* (Ait.) Maxim.)	30.0
Catnip (*Nepeta cataria* L.)	28.7
Snowberry (*Symphoricarpos albus* (L.) Blake)	28.6
Purple vetch (*Vicia atropurpurea* Desf.)	28.0
Himalaya-berry (*Rubus procerus* P. J. Muell)	27.2
Bluecurls (*Trichostema lanceolatum* Benth.)	27.1
Locoweed (*Astragalus trichopodus* (Nutt.) Gray)	27.0
Tree tobacco (*Nicotiana glauca* Graham)	25.9
Hungarian vetch (*Vicia pannonica* Crantz, floral nectar)	25.2
Turkeymullein (*Eremocarpus setigerus* (Hook.) Benth.)	25.0
Navel and Valencia oranges (*Citrus sinensis* (L.) Osbeck)	25.0
Cotoneaster (*Cotoneaster harroviana* Wils.)	24.5
Wild vetch (*Vicia* sp.)	23.1
Common vetch (*Vicia sativa* L., floral nectar)	22.6
Melanops vetch (*Vicia melanops* Sibth. and Sm., floral nectar)	22.6
Rocky Mountain bee plant (*Cleome serrulata* Pursh)	21.9
Cotton (*Gossypium hirsutum* L., Acala variety, floral nectar)	21.5
Figwort (*Scrophularia californica* C. and S.)	19.6
Tulip poplar (*Liriodendron tulipifera* L.)	19.6
Flowering currant (*Ribes sanguineum* Pursh)	18.9
Blue gum (*Eucalyptus globulus* Labill.)	17.0
Locoweed (*Astragalus asymmetricus* Sheld.)	16.0
Manzanita (*Arctostaphylos* spp.)	16–50
Avocado (*Persea americana* Mill.)	15.2
Madrona (*Arbutus menziesii* Pursh)	15.0
Sour cherry (*Prunus cerasus* L.)	15–40
Eucalyptus (*Eucalyptus* sp.)	13.4
Yellow cleome (*Cleome lutea* Hook.)	11.0
Apricot (*Prunus armeniaca* L.)	5–25
Pear (*Pyrus communis* L.)	4–30

These plants are shown to be very different in the concentration of nectar sugar, the extremes in these average values being about 4 and 65 percent. In general, one species or variety appears to have a rich or poor nectar in comparison with another, irrespective of geographical location. Humidity, the rate of evaporation, the shape of the blossoms, and perhaps other factors affect the concentrations of all. The values may change somewhat as additional data are obtained from areas which differ in climate, irrigation practice, and soil. A range of about 10 percent in concentration among the blossoms of the same kind at any given time has been observed in numerous places.

POLLEN CHARACTERISTICS

The characteristics of the pollens of some miscellaneous plants are shown in table 14.

COMPETITION AMONG BLOSSOMS FOR INSECT VISITORS

The time of blossoming of the various plants in a locality is an important factor in bee activity, for plants that blossom simultaneously must compete for insect visitors. The time of fruit-tree blossoming varies by 2 weeks from year to year. The average blossoming dates for almond, apple, apricot, cherry, peach and nectarine, and pear and plum trees at Davis, Calif., are shown in figure 7. The same general sequence occurs at Camino, although all species bloom about 3 weeks later than at Davis.

TABLE 14.—*Characteristics of pollen on the plant and as collected by the honeybee for various times and places*

Plant	Time blossoms are open	Relative quantity on plant	Characteristics of bee load		
			Color	Size	Other
Alfalfa	All day[1]	Medium	Pale brownish yellow	Small.	
Almond (*Prunus amygdalus* Batsch)	do	Abundant	Yellow, fading to pale green	Large.	
Apple	do	do	Pale yellow	do	Hairy.
Apricot	do	Medium	Brownish yellow	Medium	Gummy.
Asparagus (*Asparagus officinalis* L.)	do	Abundant	Pinkish red	Large	Mealy.
Cherry	do	Limited	Brown	Small	Gummy.
Cotton	Late forenoon	Abundant.			
Dandelion	Morning	do	Orange	Large	Oily.
Alfileria	For most part early forenoon	do	Red	do	Mealy.
Madroña		Practically none.			
Manzanita		do.			
Milkthistle (*Silybum marianum* (L.) Gaertn.).	All day	Abundant	Pale purplish	Medium to large	Mealy.
Morning glory (*Convolvulus arvensis* (L.).	First half of forenoon	Medium	White	Small	Do.
Mustard	Forenoon especially	Abundant	Yellow	Medium	Gummy.
Orange:					
Navel		None.			
Valencia	All day	Medium	Yellowish	Small to medium	Mealy.
Peach and nectarine	do	do	Brownish yellow	Medium.	
Pear:					
Bartlett	All day, but morning especially	Abundant	Pale greenish yellow	Large.	
Winter Nelis	do	Less abundant	do	Medium to large.	
Pine (*Pinus* spp.)	do	Abundant	Near white	Large	Powdery.
Plum	do	Variable; limited in many varieties.	Browns	Small to medium.	
Redmaids (*Calandrinia ciliata* (R. and P.) D. C.	Middle of day	Medium	Orange	Medium	Oily.
Sweetclover:					
White	All day	do	Dark yellow	do	Gummy.
Yellow	do	Abundant	Yellow	Large.	
Yellow star-thistle	do	do	do	Medium to large.	
Wild buckwheat	Morning especially	Medium	Brownish yellow	Small to medium.	

[1] Numerous blossoms remain untripped.

That bees shift from one plant to another in search of rich nectar has already been observed. In Tulare County, Calif., on April 28, 1938, a shift from mustard to orange occurred. This day, following a showery one, was fairly humid, warm (76° F. maximum), partly cloudy, and practically calm. The nectar in a mustard blossom is exposed, whereas considerable protection is afforded by the tubular orange blossom. During the early forenoon bees were absent from orange but numerous on mustard; the average sugar concentrations of the respective nectars at this time were 19.7 and 43.0 percent. As the day advanced, the supply of mustard nectar became more limited and the water evaporated from orange nectar. These changes brought about an almost complete shift of the bees to orange blossoms by 3 p. m., which then had an average nectar-sugar content of 28 percent. The bees seemed to be scouting over the blossoms to select those with the richest nectar. At 4 p. m. the average sugar concentration of nectar from their nectar sacs was 40.9 percent. Nectar collected at 3 p. m. by pipette from 52 blossoms on protected and exposed parts of the trees revealed a wide range in sugar content, from 16 to 43.2 percent.

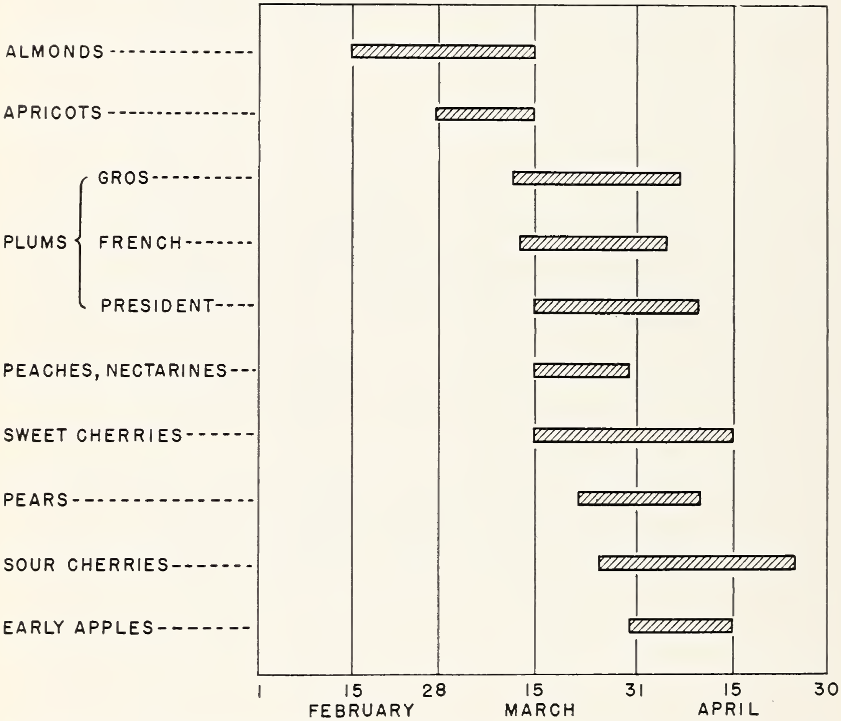

Figure 7.—Average blossoming periods of some fruit trees at Davis, Calif. The data are from the records of the University of California, by W. P. Tufts, G. L. Philp, A. H. Hendrickson, et al.

Another excellent example of en masse shifting came under observation at Camino on April 22, 1933, when the bees almost deserted plum blossoms for manzanita at about 10 a. m., but came back in large numbers to the plums in midafternoon, when the supply of manzanita nectar appeared to be somewhat exhausted. From 8:15 a. m. to 4:35 p. m. the sugar concentration of Gros nectar had nearly doubled (table 9), and this nectar was very abundant throughout the day. By this date apple nectar was becoming abundant, but there were almost no blossoming apple trees less than 0.7 to 1 mile distant, whereas the plums were near the beehives and some manzanita was within 40 rods.

Plants must also compete for insect visitors in search of pollen. Seasonal conditions frequently cause bees to gather pollen from a plant that might be neglected at other times; for example, the tiny chickweed blossoms are freely worked for pollen only in the early spring when other sources are scarce. Such competition was evident on cotton and bluecurls late in September 1938 in the San Joaquin Valley. Cotton had a large quantity of pollen per blossom, which appeared to be easily accessible; yet bluecurls, with a rather limited supply, was worked for the green pollen, and not one bee could be found collecting the white cotton pollen. The grains of cotton pollen are very large, with sharp spines, similar to those of the pollen of the cultivated hollyhock. Sunflower blossoms were also being neglected, the bees preferring spikeweed. The reason for such selection is not yet established, although we know that some pollens are far richer than others in certain constituents, especially carotin and proteins,[5] and it is possible that the bee knows much more about this than man does. It is also possible that some pollen grains are too large for the bees to manipulate easily.

At Camino the only selection noticed with reference to the pollen from the plum varieties had to do with convenience, the bees appearing to take pollen that was most abundant and easy to gather. All three of the plum varieties present gave a moderate amount of pollen, much more than other varieties of plums frequently grown elsewhere, but the bees apparently preferred pear pollen. The anthers on pear were much larger, and a full load was obtained from about half as many blossoms.

FLIGHT ACTIVITY OF THE HONEYBEE COLONY

Weather

An ideal day for honeybee flight is warm, clear, and calm. Bees seldom leave the hive if the temperature is below 50° F. In the mountains the bees have a short working day because of the low temperature in the morning and the evening. Wind greatly reduces field-bee activity, and as a rule bees do not fly out in large numbers when it is cloudy. Even a temporary shadow from a thick cloud causes partly loaded field bees to return quickly to the hive.

Orientation and Flight Capacity

Whenever honeybees are moved to a new location, they require, during good weather, 3 or 4 days to get oriented to their surroundings;

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[5] Unpublished data by F. E. Todd, U. S. Department of Agriculture, and Ormond Bretherick, University of California.

consequently, the distance of their flight from the hive is very short during this time. From a long-established hive the bees go 1½ miles or farther; they have been known to fly as far as 8½ miles in search of nectar and pollen.

Each bee old enough for outside work may go afield four or five times in 1 day. It has been estimated that 822,720 bees issued from the 16 colonies at the Caldwell orchard on a good flight day in 1933. Just how many of them visited the fruit blossoms is unknown, but on some days fruit pollen constituted about 85 percent of the pollen loads collected.

Pollen Gathering

The manner in which an insect visits blossoms, as well as the number and kind of blossoms visited consecutively, has an important bearing on its value as a pollinating agent. A small insect, which walks into a blossom without touching the anthers or stigma, could be of little use in effective pollen transfer. When collecting pollen from some plants, the honeybee does not alight on a blossom, but works it while sustaining itself in the air somewhat in the manner of a nectar-gathering hummingbird. The tiny thin-stemmed gilias and the California buckeye with its long protruding anthers are frequently thus visited. The pollen-gathering bees work alfalfa blossoms, at times, in a peculiar manner not yet well understood.

The structure of some blossoms prevents the bees from readily working them for pollen. For example, it seems to be difficult for bees to collect pollen from the juglike blossoms of manzanita. In the pollen taken from the bees during the 3-year period at Camino no manzanita pollen was found. However, subsequent observations showed that where manzanita was the only source the bees removed a small amount of pollen by using the mouth parts as a swab.

To obtain nectar, especially on cherry and peach blossoms and to some extent on apple, the bees must literally force their way among the numerous stamens and the pistil. Consequently, bees visiting blossoms for nectar only, as well as the pollen collectors, are important pollen distributors, for their body parts become covered with pollen grains (figs. 8, 9, and 10). This fact refutes the conclusion of Brittain (*3*), who minimized the value of nectar-collecting honeybees in the transfer of pollen on apple.

At the Gold Hill orchard on March 31 and April 1, 1931, an attempt was made to count the pear blossoms a bee visited in collecting a full load of either pollen or nectar. Because of the difficulty in following the flight of an individual bee, only 2 bees were successfully observed until they had gathered a full load. One bee visited 84 Winter Nelis blossoms for a full load of nectar, and the other visited the same number of Bartlett blossoms to secure her load of pollen. Each of these bees could have thus been instrumental in causing 84 pears to set. A bee collecting dandelion pollen was observed to visit more than 100 blossoms to secure a full load.

Certain days are notably better for pollen carrying than others. Table 15 shows the percentage of bees carrying pollen into 10 hives for one period on an unusually good day in 1932. These figures indicate intense bee activity for both pollen and nectar. Pear, plum, apple, cherry, mustard, and two undetermined nonfruit pollens were

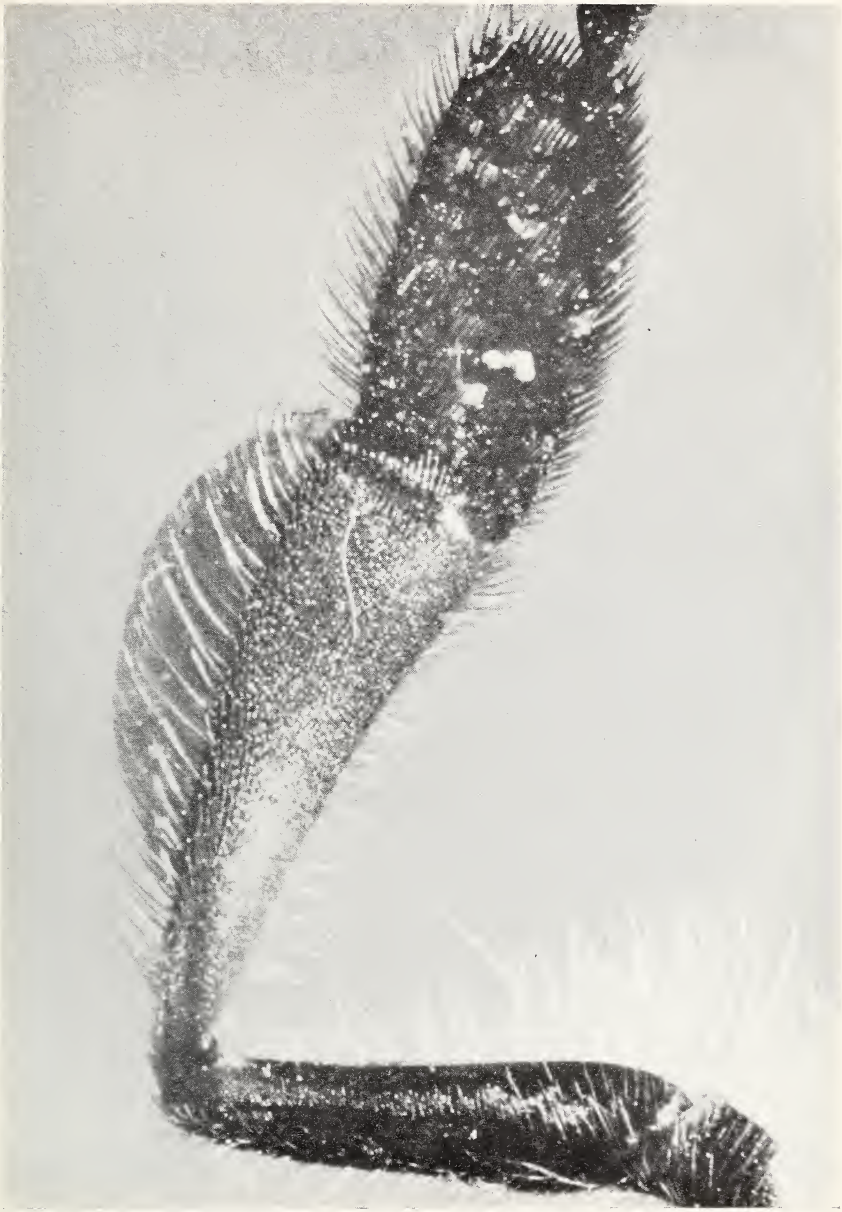

FIGURE 8.—Greatly enlarged view of a honeybee's leg, showing the loose pollen grains, which appear as white dots.

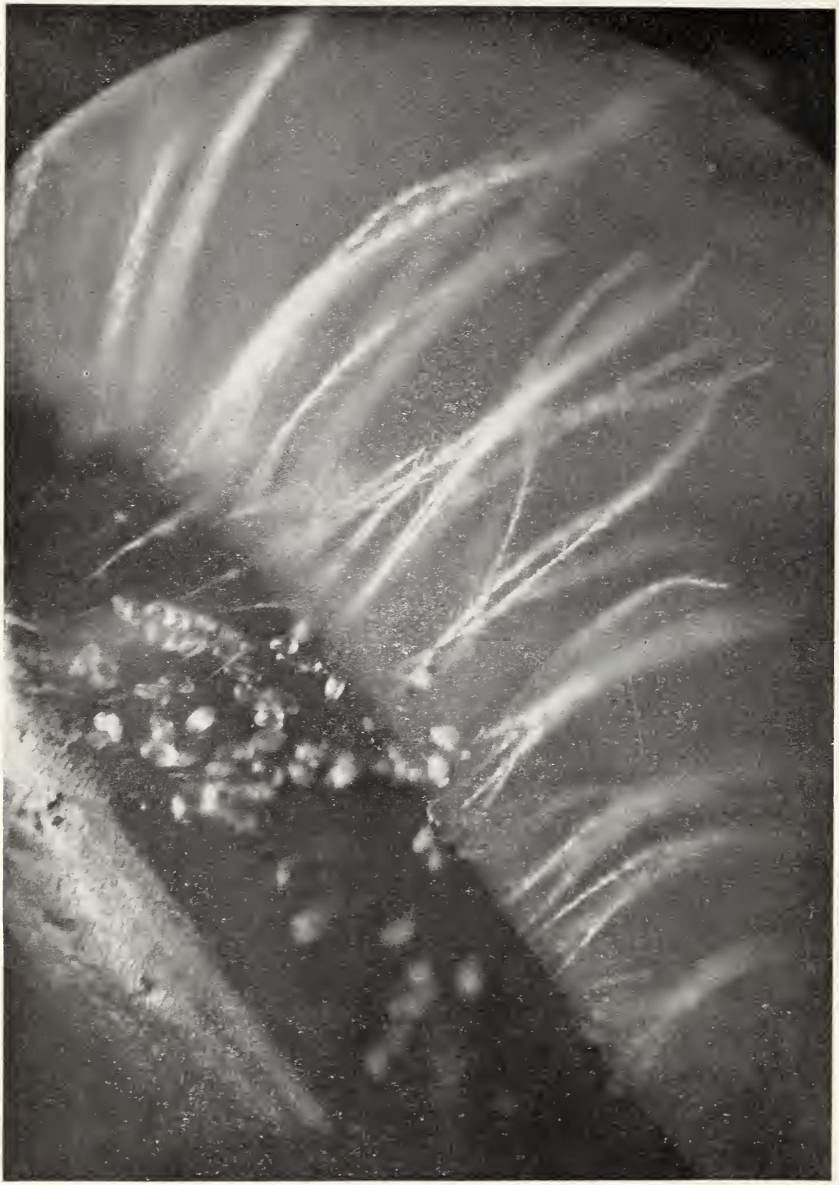

FIGURE 9.—Femur of a bee's leg, showing hairs with pollen grains. As the bee pushes into the blossom for nectar or pollen, these grains come in contact with the viscid surface of the stigma and bring about pollination. This field bee was caught when entering the hive as it returned from a nectar-collecting trip.

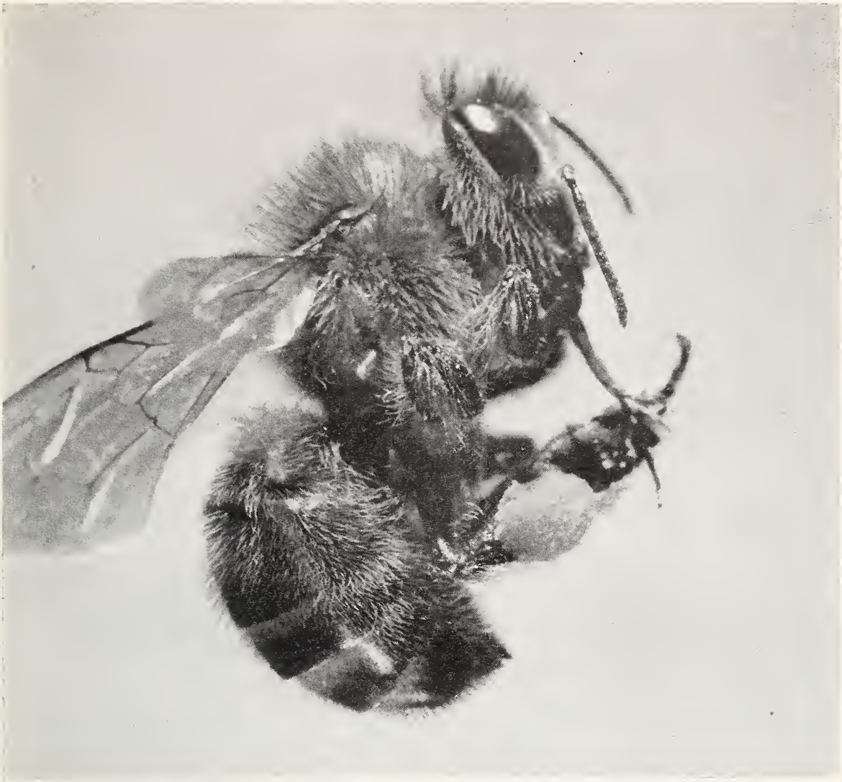

Figure 10.—Side view of a pollen-collecting honeybee, showing myriads of loose grains on the body parts.

being carried at this time, the relative abundance being in the order named. The blossoming plants within a radius of 1½ miles included cherry, apple, pear, peach, plum, madroña, manzanita, *Chamaebatia*, pea (*Lathyrus*), chickweed, alfileria, mustards, flowering quince, maple, willow, wild radish, oak, ceanothus, crowfoot, and shootingstar.

Table 15.—*Rate of return of field bees to the hive and percentage of pollen carriers, 12:15 to 1:45 p. m., April 6, 1932, Camino, Calif.*

Colony No.	Time for arrival of 100 bees	Bees carrying pollen	Colony No.	Time for arrival of 100 bees	Bees carrying pollen
	Seconds	*Percent*		*Seconds*	*Percent*
1	29	22	7	39	14
2	60	21	8	34	23
3	39	14	9	32	20
4	30	15	10	36	14
5	37	22			
6	35	20	Average	37.1	18.5

In the light of these observations on pollen-gathering activities of bees and the fact that over three-quarters of a million bees were estimated to issue from the colonies at Camino in a single day, the tremendous value of bees as pollen distributors becomes obvious.

Comparison of Overwintered Colonies and Package Bees

Because severe winter conditions reduce the number of adult bees, each spring many packages of bees are shipped from the South to reestablish or strengthen colonies in the more northern States and Canada. There has been considerable disagreement over the relative pollinating value of package bees and overwintered colonies. This problem has been discussed by Paddock (*7*), Carr (*4*), Woodrow (*12*), and Phillips (*10*).

Data comparing the population, the flight activity, and the pollen collecting of the overwintered colonies and of package bees are presented in the following paragraphs.

POPULATION

When first established package bees have no brood, and theoretically all are available for field work. But since some of the bees in a package are bound to be near the end of their life span of 6 weeks, and will therefore die very shortly, there is a decline in population before the young bees are ready to emerge. As soon as the brood is started among package bees, the number of available workers in the field will, of course, be reduced. In the North many of the overwintered colonies are of little value in fruit-blossoming time because of the great reduction in their population and because of the age of their workers. In the South, however, the overwintered colonies, because of the long brood-rearing periods, are approaching the peak of their population at fruit-blossoming time and have an abundance of young workers to send to the field.

In 1931 only package bees were taken into the Caldwell orchards. No flight counts are presented for this season, but the bees were numerous on the fruit blossoms near the apiary. In 1932, 10 overwintered colonies, brought from the Sacramento Valley, and 10 packages (five 5-pound and five 3-pound units) of bees were used. The population of the overwintered colonies exceeded that of the packages, even the 5-pound units, at the start. In 1933, 10 overwintered colonies, equalized to approximately 5 pounds of bees each, and six 5-pound packages of bees were used. In both years emerging brood soon brought the population up to more than 5 pounds in each overwintered colony, while the packages lost population daily because of the absence of such brood. Thus, in 1933 the overwintered colonies, with an initial population of 18,000 adult bees and an average of 4.6 frames of brood, almost doubled in population over a period of 11 days, while the broodless packages, with the same initial population, lost about 40 percent of the bees.

It should be pointed out that the condition of the populous colonies from the warm Sacramento Valley at the time the observations were made is very different from that of most of the overwintered colonies observed during fruit-blossoming time in part of Oregon and in Washington.

Table 16 gives data on the size of the overwintered colonies and the packages used in 1932, at the beginning and the end of the 11-day observation period. Since the colonies were so irregular in brood, the increase in adult bees was erratic; nevertheless all but one of the overwintered colonies became much more populous and all the broodless packages much less so.

TABLE 16.—*Populations of overwintered and package colonies used in pollination work at beginning and end of observation period at Caldwell's orchard, Camino, Calif., 1932*

Overwintered colonies			Package colonies	
Adult population on—		Frames of brood, Mar. 30	Adult population on—	
Mar. 30	Apr. 9		Mar. 30	Apr. 9
Thousand	*Thousand*	*Number*	*Thousand*	*Thousand*
15	35	4¼	[1] 18	13
22	26	3½		13
24	32	3¾		10
26	49	5¼		10
35	33	5½		10
31	35	4½	[2] 11	7
31	37	5½		3
29	35	4¼		4
31	42	4½		4
26	39	2¾		7

[1] 5-pound packages.
[2] 3-pound packages.

POLLINATION VALUE AS SHOWN BY NUMBER OF FLIGHTS

From time to time numerous counts were made of both incoming and outgoing bees of the overwintered and of the package colonies. Samples of the data are presented in tables 17 to 20.

The average time required for 100 bees to issue from and to enter the hives during a 2-hour period is shown in table 17. The overwintered colonies required only three-fourths the time used by the 5-pound packages and one-half that by the 3-pound packages. The overwintered colonies greatly exceeded the packages also in the amount of pollen carried.

TABLE 17.—*Time required by overwintered and package-bee colonies for entering and leaving the hive and the percentage of pollen carriers, 8:20 to 10:07 a. m., April 9, 1932,*[1] *Camino, Calif.*

Type of colonies	Colonies	Average time per 100 bees		Incoming bees with pollen balls
		Outgoing	Incoming	
	Number	*Seconds*	*Seconds*	*Percent*
Overwintered colonies	10	66.4	47.2	20.4
5-pound packages	5	92.4	67.2	6.4
3-pound packages	5	120.0	130.0	8.6

[1] All groups liberated on Mar. 28.

Flight data illustrating the number of bees from overwintered and from package colonies issuing for field work, and the number returning, with the percentage carrying pollen balls, are shown in table 18. On this date the differences in the number of bees issuing from the overwintered colonies and the 5-pound package colonies do not appear to be significant, but over a 2-week observation period the margin increased daily in favor of the overwintered colonies. As a rule more pollen was carried by these colonies than by the package bees. The percentage of bees with pollen was surprisingly large at times, particularly during the early part of certain days.

TABLE 18.—*Summary of flight data for 10 overwintered colonies and 6 packages of bees during 6 observation periods on April 14, 1933,*[1] *Camino, Calif.*

Time of day	Average outgoing bees per minute		Average incoming bees per minute		Average bees entering with pollen balls	
	Colonies	Packages	Colonies	Packages	Colonies	Packages
	Number	*Number*	*Number*	*Number*	*Percent*	*Percent*
8:20 to 9:10 a. m.	60.5	68.3	72.2	90.3	-----	-----
10 to 11:25 a. m.	53.9	50.0	70.4	56.0	8.2	4.6
1:30 to 2:30 p. m.	69.3	63.2	80.5	50.0	5.6	3.6
2:35 to 3:10 p. m.	63.9	52.4	81.8	58.4	3.4	5.1
3:10 to 4 p. m.	47.0	36.2	72.4	36.2	7.3	4.4
4:05 to 4:45 p. m.	39.6	35.1	65.2	32.8	6.4	3.7

[1] All groups liberated on Apr. 9. During the observations the temperature ranged from 63° to 66° F. The relative humidity at 8:30 a. m., 12 m., and 4 p. m. was 66, 50, and 55 percent, respectively.

Representative flight data for overwintered and package colonies in 1932 and 1933 are given in table 19. In each case only the initial morning count is shown. The variation in even the overwintered colonies in 1933 is apparent. The 1933 data were taken near the end of the observation, 13 days after those given in table 18, and at this time the difference in favor of the overwintered colonies was significant. The number of pollen carriers showed great variation between colonies, but as a rule all the overwintered colonies exceeded the packages both in the amount of pollen carried and in flight activity. The pollens carried by the bees on this day were primarily from pear, plum, mustard, apple, cherry, alfileria, and a few miscellaneous sources.

TABLE 19.—*Outgoing flight data of overwintered and package colonies on 1 day each in 1932 and 1933, Camino, Calif.*

Type of colonies	Apr. 9, 1932			Apr. 27, 1933		
	Colonies	Time for 100 bees		Colonies	Time for 100 bees	
		Range	Average		Range	Average
	Number	*Seconds*	*Seconds*	*Number*	*Seconds*	*Seconds*
Overwintered	10	45–84	55	10	22–54	39
Packages:						
5-pound	5	56–82	65	6	35–66	54
3-pound	5	72–246	153	-----	-----	-----

Table 20 summarizes the flight counts for all the observation periods of the 1933 season in the Camino fruit area. These records are considered to represent the potential pollination value of the bee units used. At first the number of bees issuing from the packages and overwintered colonies was not greatly different, but the colonies eventually surpassed the packages. The predominating pollen was from pear.

TABLE 20.—*Summary of outgoing flight data for overwintered and package colonies in April 1933, Camino, Calif.*

Date in April	Time of day	Average outgoing bees per minute	
		Overwintered colonies	Packages
		Number	*Number*
13	10:30 to 11:40 a. m.	51.5	63.4
14	8:30 a. m. to 4:45 p. m.	55.5	50.8
15	8:05 a. m. to 2:30 p. m.	57.0	58.1
19	8:45 a. m. to 5 p. m.	67.5	94.2
20	8:30 a. m. to 4:25 p. m.	78.3	89.4
21	8:30 a. m. to 2:43 p. m.	134.0	148.9
22	7:05 a. m. to 4:40 p. m.	106.0	102.3
23	8 a. m. to 2:25 p. m.	85.0	83.4
24	8:30 a. m. to 4:55 p. m.	101.2	69.8
27	8 a. m. to 5:30 p. m.	124.1	84.8
28	8 a. m. to 12:15 p. m.	109.7	75.1

At Hood River, Oreg., on several days in May 1935, flight counts were made on 5 lots of bees rented to orchardists. Each lot selected was owned by a different man. There were 77 overwintered colonies and ten 5-pound packages in the series. The flight from the package bees was arbitrarily set at a value of 100 percent, and the colonies were evaluated on this basis. Fifty colonies in 2 of the lots were rated at 115 percent, 12 colonies of another lot at 80 percent, and the 15 remaining colonies in a third location at 6 percent. On this basis 20 of the weak colonies were required to equal 1 strong colony in flight activity. The unusually strong overwintered colonies, moved in from south-central Oregon, had 5 or more frames of brood, and the weakest lot, from western Oregon, not more than 2 frames, and sometimes no brood at all.

Undoubtedly the bee colony, no matter what the kind, which throws the greatest force of worker bees into the field is of most value for pollination purposes. These observations have shown that the strong overwintered colonies surpass the package bees in population and in ability to send large hordes of workers to the field. Wherever winter conditions make maintenance of such colonies impossible, growers must resort to the use of package bees. Growers renting bees should therefore insist on securing large, strong colonies, and in purchasing should buy the larger packages.

SUMMARY

The behavior of honeybees in visiting blossoms for nectar and pollen has been observed over a period of years in various parts of California and in Oregon, especially in experimental orchards at Camino, Calif., to obtain information that would aid orchardists and seed growers in improving the pollination of their crops.

In the Camino district honeybees were by far the most common blossom visitors (62 percent), blowflies were next (23 percent), and other insects were scarce. The bees were practically the only distributors of pear pollen. The closer bees were placed to the pear trees, the more effective they were as pollen distributors.

Considerable numbers of honeybees were observed visiting blossoms that had been emasculated. It is therefore unsafe to depend on emasculation for plant-breeding purposes, without covering the blossoms.

Between species of plants there is a wide range in the quantity of nectar secreted and in its sugar concentration. As the relative humidity decreased, there was a consequent increase in the percentage of sugar in all nectars, although not a proportional increase because of the difference in the structure and position of nectar glands in various blossoms.

For 1 day at Davis, Calif., the following average sugar concentrations of nectar from fruit blossoms were obtained: Apple 46.2, peach and nectarine 28.9, plum 25.8, sour cherry 23.5, Winter Nelis pear 9.9, and Bartlett pear 7.9 percent. The low sugar concentration for Bartlett pear may be below the point of attractiveness to the honeybees, at least where richer nectars are available. The nectars of apple and sweet cherry blossoms, on the other hand, are especially attractive, for at times the bees practically abandon all other fruit blossoms for these two kinds.

Manzanita plants most advanced in blossoming afforded the richest nectar, and bees selected them in preference to plants with recently opened blossoms. These facts explain why the yield of manzanita honey improves at the end of the blossoming period.

Additional data on the sugar concentration of other nectars show a range from 65 percent for alfileria to 11 percent for yellow cleome.

Data indicating the characteristics of the pollen of some plants show a wide range in quantity, color, and size of the bee load.

Plants that blossom simultaneously must compete for insect visitors. Bees shift from one plant to another in search of nectar having the highest sugar concentration, but the reason for their selection of certain plants for pollen is not yet established.

Wind greatly reduces the activity of field bees, and as a rule bees do not fly out heavily when it is cloudy.

From a long-established hive the bees go a mile and a half and sometimes much farther in search of nectar and pollen, but after being moved to a new location they do not fly far for the first 3 or 4 days.

The honeybee is an important pollination agent because in visiting a blossom for either nectar or pollen it brushes the flower parts, covering its body with pollen, and also because it usually collects only one kind of pollen on a trip. One bee was observed to visit 84 Bartlett pear blossoms to secure her full load of pollen. It was estimated that on a good flight day 822,720 bees issued from the 16 colonies placed in the Caldwell orchard.

Strong overwintered colonies were found to surpass the package bees in population, flight activity, and the amount of pollen gathered, and 5-pound packages were more effective than smaller units. Therefore, where winter conditions prohibit the maintenance of overwintered colonies, the larger packages should be purchased.

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